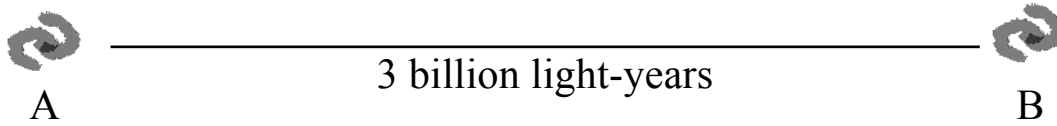


Expansion, Lookback Times, and Distances

When the universe was 4 billion years old, Galaxy A was 3 billion light-years away from Galaxy B, as shown below. Imagine that the universe was not expanding, so the distance between Galaxy A and Galaxy B would not change over time.



- 1) A star explodes in Galaxy B producing a large amount of light. How long will the light from this explosion take to reach Galaxy A?
- 2) How far did the light travel on its journey to Galaxy A?
- 3) How old will the universe be by the time the light from the explosion reaches Galaxy A?

Because light takes time to travel from place to place in the universe, when we look at the night sky we are seeing stars and galaxies as they appeared in the past. For example, if we see a galaxy 1 million light-years away, we are seeing what the galaxy looked like 1 million years ago. We say this galaxy has a lookback time of 1 million years. Lookback time is the amount of time light takes to travel to us from a distant object.

- 4) What is the lookback time inhabitants of Galaxy A associate with Galaxy B when they see the light from the explosion?

The real universe is expanding. This means the distance between galaxies is constantly increasing. Imagine that Galaxy A and Galaxy B are in an expanding universe.

- 5) While the light from the explosion is traveling from Galaxy B to Galaxy A, does the distance between the two galaxies stay the same, become larger, or become smaller?
- 6) By the time the light from the explosion in Galaxy B reaches Galaxy A, is the distance between the galaxies more than, less than, or exactly 3 billion light-years?
- 7) By the time the light from the explosion in Galaxy B reaches Galaxy A, has more than, less than, or exactly 3 billion years elapsed since the star exploded?

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- 8) By the time the light from the explosion in Galaxy B reaches Galaxy A, will the total distance traveled by the light be more than, less than, or exactly 3 billion light-years?
- 9) When the inhabitants of Galaxy A see the light from the explosion in Galaxy B, are they looking at an event with a lookback time of more than, less than, or exactly 3 billion years?
- 10) In the space below provide a sketch that explains the reasoning behind your answers to questions (6-9).

Expansion, Lookback Times, and Distances

- 11) Consider the discussion between two students regarding their ideas about two distant galaxies in an expanding universe.

Student 1: *Let's say light takes 5 billion years to travel from one galaxy to another. This means the two galaxies were separated by 5 billion light-years when the light began its journey.*

Student 2: *If the light traveled for 5 billion years, then the distance between the two galaxies must have been less than 5 billion light-years when the light began its journey because the distances between galaxies are always increasing in the expanding universe.*

Do you agree with either or both of the students? Explain your reasoning.